**Licensing and Technology Transfer Opportunity: Manipal University**

**Title of Technology Available**:

MECHANICALLY VARIABLE MAGNETIC FLUX BASED BRUSHLESS DC DRIVE MOTOR FOR ELECTRIC VEHICLES "FreeEngage"

**Brief Description of Invention**:

The invention presents a novel brushless DC drive that radially varies distance between stator and rotor for various stages of drive operation.

Magnetic flux reduces as distance between stator and rotor increases (Inverse Cube Relation). When the magnetic flux is reduced to a negligible value, then the motor acts like a freely rotating shaft with only bearing and windage losses. Reconversion losses are eliminated when the vehicle is required to maintain speed for short distances. This invention aims at utilizing this concept to vary the magnetic association of the stator with the rotor in heavy momentum applications like Electric Vehicles when continuous variation of drive speed is required. Back emf is eliminated when magnetic flux is zero.

Thus at mid-range speeds for short duration,

1) Supply voltage need not be provided to maintain drive speed.
2) Magnetic Parasitic Drag (MRD) is eliminated between stator and rotor.

These benefits eliminate ON-board battery power needed to maintain speed for short distances (appx 300m if the initial speed is 60kmph) during the driving cycle, thus enhancing battery life and improving efficiency.

**Brief Background of Invention**:

When a heavy mass object (an EV) is rotating on the shaft on an electric motor by virtue of its own momentum only, due to Lenz's law, the rotating armature; of the motor; in the fixed magnetic field generates an induced emf across the coils and as a consequence creates an opposing torque. The opposing torque slows down the motor shaft. This induced emf is currently used to recharge the battery even when braking is not applied. Unfortunately, this a conversion with losses and energy restored is a factor of efficiency of the motor, typically 70 – 85 % or 0.7 – 0.85.

Lenz's law states

> "EMF induced in a conductor; due to change in magnetic flux associated with it; is generated in such a direction that it opposes the cause producing it and its magnitude is proportional to the rate of change of magnetic flux"

However, if that magnetic field is removed, then no opposing force is generated and the shaft rotates freely; only restrained by losses of bearings that support the shaft. Since a vehicle has to vary speeds constantly, re-conversion losses are significant. This invention aims at utilizing this

concept to vary the magnetic association of the stator with the rotor; by varying the distance between the aforementioned entities; as per the state of operation of the motor. In the process, we wish to eliminate re-conversion efficiency losses when the electric vehicle is maintaining its speed or decelerating slowly and braking isn't needed.

**Describe the final product**:
The final product is a typical radial BLDC drive with the stator divided into two halves that separate about rotor axis symmetrically. The mechanical separation is hydraulically actuated and the energy needed to separate them can be provided from the existing hydraulic system of the vehicle. Since the separation is radial and not axial, the force required to displace the stator is negligible in the zone of 5mm of actuation.

**Technological Domain (Keywords)**:
Polyphase Drives. BLDC Synchronous PM machines. Mechanical Flux Variation. Electric Vehicle Drive Train Technology. Battery Life Enhancement Techniques. Negation of Parasitic Drag in PM machines.

**Proof of Concept**:
Magnetic flux variation with distance follows the inverse cube rule. Thus by increasing the stator rotor distance from 0.1mm to even just 1mm, the magnetic flux becomes $1/1000^{th}$ and thus the mechanical power reconverted to electrical power also become $1/1000^{th}$. When the magnetic flux is reduced to a negligible value, then the motor acts like a freely rotating shaft with only bearing losses.

**Stage of Development**:
3D software prototype.

**What are the unique advantages your innovation has compared to the competition**:

All current machines in the market including BMW i3, Tesla Roadster are focusing on reducing weight and other specs but do not tackle the problem of back emf and vehicle efficiency during the driving cycle. A significant portion of city driving is spent between acceleration and maintaining speed for some distance before having to brake again.

In an EV the inherent nature of motors demands that a supply voltage be provided to maintain speed because of the back emf. Thus, even to maintain speed, power is wasted. In the "FreeEngage" machine however, simply changing the air gap thickness by a few mm eliminates all back emf regulation constraints and magnetic parasitic drag without affecting regenerative capabilities needed during braking

The invention is a machine of interest to all companies manufacturing EVs such as Mahindra and Mahindra, Ford, BMW, Nissan, Toyota, Honda, etc.

Intellectual Property Status: Complete Specification filed in India – 201941051085. Year - 2019